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# From Lyrics by al-Fazārī to Lectures by al-Fārābī: Teaching Astronomy in Baghdad (750–1000 C.E.)

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## Introduction

Astronomy in the Islamic World in the first millennium C.E. has left a wealth of evidence. We know of 671 Arabic astronomical works from that epoch, 623 of which are still preserved in manuscripts.<sup>1</sup> We know 356 authors of astronomical works, 91 of whom were active in Baghdad. These figures show that astronomy was no marginal phenomenon. The questions of how these astronomers were trained and what methods were used to acquire such specialized skills may seem obvious, but they have not yet been earnestly addressed.

In this article, three groups of sources representing three phases of educational methods, used between the 8th and 10th centuries, will be discussed. In the first phase (750–800 C.E.) basic education was achieved through memorization. This is evident from the documented existence of a number of didactic poems on astronomy. In the second phase (800–900 C.E.) basic training was done by manually performing operations with the moveable parts of a physical model of the heaven such as an astrolabe, an armillary sphere or a celestial globe. This is corroborated by a corpus of instruc-

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<sup>1</sup>Rosenfeld, Boris Abramovich and Ekmeleddin İhsanoğlu: *Mathematicians, astronomers, and other scholars of Islamic civilization and their works (7th-19th c.)*. Istanbul 2003 : 14–156

tional texts by al-Khwārizmī and an early astrolabe which was constructed for educational purposes. In the third phase (900–1000 C.E.) intellectual formation started to be organized by lectures in which textbooks were used. This is documented by the emergence of commentaries on Ptolemy's *Almagest* and al-Farghānī's *Fuṣūl*.

## First Phase: Memorizing Poems

In the history of astronomy we have to face the problem of a “dark century” in the Mediterranean and the Middle East. From the middle of the 7th to the middle of the 8th century there are no traces of any kind of activities in the field of mathematical astronomy. Later reports on the astronomical achievements of the Arabs in pre-islamic times have to be regarded with caution. They describe astronomical concepts which could hardly have been Arabian in origin.<sup>2</sup> In any case, the traditional Arabic knowledge about celestial phenomena was limited to what today is called “folk astronomy”.<sup>3</sup>

The revival of mathematical astronomy in the Islamic world took place shortly after the ‘Abbāsid revolution (i. e. after 750 C.E.) . Most of what is described in modern historiography on the early phase of this scientific Renaissance is based on Ibn al-Nadīm's *Fihrist*, written two centuries after the events. In the case of the translation of Euclid's *Elements* Sonja Brentjes has shown how unreliable reports in the *Fihrist* can be.<sup>4</sup>

None of the earliest Arabic works on astronomy are preserved. The case is simi-

<sup>2</sup>Thomann, Johannes: Explicit and implicit intercultural elements in the Zīj of Ḥabaš al-Ḥāsib. In *Proceedings of the 25th Congress of the Union Européenne des Arabisants et Islamisants* (Naples, 8-12 September 2010) Forthcoming; Schaefer, Bradley E.: Date and place of origin of the Asian lunar lodge system. In *Astronomy and Cultural Diversity (Proceedings of the International Conference 'Oxford VI and SEAC 99')*, page 283–287 1999; Varisco, Daniel Martin: The origin of the answā' in Arab tradition. *Studia Islamica* 74, (1991) 5–28 Kunitzsch, Paul: *Untersuchungen zur Sternnomenklatur der Araber*. Wiesbaden 1961 : 21–23.

<sup>3</sup>Varisco, Daniel Martin: Islamic folk astronomy. In *Astronomy across Culture*, page 615–650. Kluwer Academic Publishers; King, David A.: Folk astronomy in the service of religion. the case of Islam. In *Astronomies and Cultures*, page 124–138. University Press of Colorado.

<sup>4</sup>Brentjes, Sonja: Euclid's *Elements*, courtly patronage and princely education. *Iranian Studies* 41, (2008) 441–463:444.

lar to those of the Pre-Socratic Greek philosophers. As a base for further research in early Arabic science, a work like Hermann Diels' groundbreaking *Fragmente der Vorsokratiker* is needed. The separation of fragments from reports is crucial in Diels' collection. Only literal quotations from original works are presented as true fragments ("eigentliche Fragmente") and, for each author, they are grouped together as section B, while all biographical and doxographical reports ("biographisches und doxographisches Material") are collected under section A.<sup>5</sup>

David Pingree made initial steps in his two articles on the fragments of Ya'qūb b. Ṭāriq and al-Fazārī, both astronomers active in the time of al-Manṣūr (754–775 C.E.),<sup>6</sup> but unfortunately he made no distinction between reports and fragments. From the 29 fragments of Ya'qūb b. Ṭāriq listed by Pingree only eight contain literal quotations from two original works.<sup>7</sup> 30 fragments of al-Fazārī listed by Pingree contain seven true fragments from three original works.<sup>8</sup>

Of the five works from which fragments still exist, one by al-Fazārī deserves our attention as it suggests how the teaching of astronomy took place.

Biographical works mention the existence of *Qaṣīda fī 'ilm al-nujūm* ("A qasida on the science of the stars") by Muḥammad al-Fazārī.<sup>9</sup> Al-Yāqūt quotes the first two, and al-Ṣafadī the first four lines of this poem. Another portion of nine lines is mentioned in al-Bīrūnī's "Teatise on shadows" (i.e. *Ifrād al-maqāl*):

الحمد لله العلي الاعظم / ذى الفضل والمجد الكبير الاركم / الواحد الفرد الجواد المنعم  
الخالق السبع العلى طباقا / والشمس يجلو ضوءها الاغساقا / والبدر يملأ نوره الآفاقا  
والقلل الدائر في المسير / لاعظم الخطب من الامور / يسير في بحر من البحور  
فيه النجوم كلها عوامل / منها مقيم دهره وزايل / طالع منها ومنها آفل

<sup>5</sup>Diels, Hermann: *Die Fragmente der Vorsokratiker*: Griechisch und Deutsch. Berlin 1903 : v.

<sup>6</sup>Pingree, David: The fragments of the works of Ya'qūb Ibn Ṭāriq. *Journal of Near Eastern Studies* 27, (1968) 97–125; Pingree, David: *Census of the exact sciences in Sanskrit*, volume 81, 86, 111, 146, 213 of *Memoirs of the American Philosophical Society*. Philadelphia 1970–1994a .

<sup>7</sup>Pingree, David, 1968, : *Tarkīb al-aflāk* No. 1, 8, 10, 11; *Al-'Ilal* No. 3, 5–7.

<sup>8</sup>Pingree, David, 1994a, : *Zīj al-Sindhind al-kabīr* No. 15, 18; *Zīj 'alā sinī al-'Arab* No. 2; *Qaṣīda* No. 1–2.

<sup>9</sup>Ibn al-Nadīm: *Kitāb al-Fihrist* 1872 ; Yāqūt b. 'Abdallāh al-Ḥamawī: *The Irshād al-arīb ilā ma'rifat al-adīb*, or, *Dictionary of learned men of Yāqūt*. 1907–1926 : al-Ṣafadī, Khalīl Ibn Aybak: *Kitāb al-Wāfi bi-l-wafāyāt* 1949

(Original orthography by H. Ritter).

Pingree's prose translation reads:<sup>10</sup>

Glory to Allāh, the High and Mighty, to whom are superiority and great  
grandeur. The most noble the unique one, the magnanimous bene-  
factor,

the creator of the highest seven in order. The sun's light brightens the  
darkness, and the full moon's light spreads to the horizon.

The sphere, revolving in its course for the greatest of affairs, moves in  
one of the seas;

On it the stars, all of them, are agents; and some of them are permanent,  
some transitory, and some rise, while others set.

The poetic cosmology of these opening verses are not representative of the other  
parts of the poem. Indeed, the rest is more technical. When al-Bīrūnī quotes a passage  
on the time passed of the day, the method for determining the hour of the day using  
a gnomon is described as follows:<sup>11</sup>

عود أو قدره لحسن القدر / ستّا وستّا واستعن بالصدر / وطوله قدرا كقدر الشبر  
فانصبغ نصبا في مكان منتو / ثم انظر الظلّ إلى ما ينتهي / فاقدره بالعود [...]   
فما بلغ ذاك من التعديد / ومن حساب ظلّك الموجود / فرد عليه مثل ظلّ العود  
والق منه ظلّ نصف يومكا / وأحص ذاك كلّ بهمكا / فإنّ في ذاك كمال أمركا  
فما بقي فاصم عليه وهنا / كائنين مع سبعين حتّى يفنا / هذا العمري واضح في المعنى

Make a stick whose graduations, for elegant measurement

Are six and six and let patience support you,

Its length being of the amount of a span.

<sup>10</sup>Pingree, David, 1994a, : 121; Yāqūt b. 'Abdallāh al-Ḥamawī, 1926, : vol. 6, 268;  
al-Ṣafadī, Khalīl Ibn Aybak, 1949, : vol. 1, 336–337:

<sup>11</sup>Kennedy, Edward Stuart, editor: *The exhaustive treatise on shadows / By Abu al-Rayḥān Muḥammad b. Aḥmad al-Bīrūnī*. Aleppo 1976 : vol.1, 191–192; al-Bīrūnī, Muḥammad Ibn Aḥmad: *Ifrād al-maqāl fī amr al-ḡilāl* 1976 : 143–144:

So set it up in a level place.

Then look at the shadow where it ends,

And measure it with the stick.

What results [ending] at the numbering

And the computation is as thy shadow at the time.

So add to it the like of the stick's shadow,

And subtract from it the shadow at noon of thy day.

Allot that, all of it, with persistence.

In that is the perfection of the affair.

What is left, divide by it here,

As two with seventy until it is finished.

This, upon my soul, is plain in meaning.

The procedure of timekeeping described in these verses is equivalent to this mathematical formula:

$$x = \frac{72}{(s+12)-s_n}$$

if we denote the shadow  $s$ , the shadow at noon  $s_n$ , and the hours since sunrise or before sunset  $x$ . The length of the gnomon is 12 units.<sup>12</sup>

The context in which these verses are quoted is significant. In chapter 23 of his “Treatise on shadows” al-Bīrūnī provides a historical account of early texts on the subject of timekeeping by shadows.

He begins by referring to the method of the Indian *Paulīśasiddhānta*, which is virtually the same as the one described in the poem of al-Fazārī.<sup>13</sup> Next, al-Bīrūnī cites literally a passage from the Arabic translation of the *Brahmasphuṭhasiddhānta* by Brahmagupta. This is not al-Bīrūnī's own translation, but an older one which he criticizes

<sup>12</sup>Kennedy, Edward Stuart, 1976, : vol. 2, 118–119.

<sup>13</sup>al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 138–139; Kennedy, Edward Stuart, 1976, : vol.1, 187–188.

and corrects on the basis of an Indian commentary on the *Brahmasphuṭhasiddhānta* by Pṛthūdakasvāmin.<sup>14</sup>

Next, al-Bīrūnī quotes a passage from a text which according to him was translated from Sanskrit in the first days of the ‘Abbāsīd dynasty.<sup>15</sup> He remarks that some Sanskrit terms are not translated and gives his own explanation of one of them. In fact the transliteration *ghaṭikāt* for Sanskrit *ghaṭikā* does not appear in other Arabic texts, and his statement that this is one of the earliest astronomical texts in Arabic has some credibility.<sup>16</sup>

Next, al-Bīrūnī explains that one member from the group of scholars who used the *Sindhind* wrote his Arabic *Zīj*-work in verse, inspired by the fact that Sanskrit astronomical works were composed in verse.<sup>17</sup>

Al-Bīrūnī quoted six verses, each consisting of three parts with corresponding final rhymes.<sup>18</sup>

If it be thy pleasure to determine the hour of the day,

Then take a stick by which [thou livest],

Which is the deed of a wise man

Who would investigate the seas (of knowledge) rich and full.

So, let thy stick be, mark well, its length

...

This is the form which al-Fazārī adopted for his *Qaṣīdah*, instead of the traditional form of the *Qaṣīdha* with monorhyme. Al-Bīrūnī explicitly points out this peculiarity. This form with three internal rhymes and the more simple variant with two internal

<sup>14</sup> al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 140–141; Kennedy, Edward Stuart, 1976, : vol.1, 189.

<sup>15</sup> al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 141–142; Kennedy, Edward Stuart, 1976, : vol.1, 189–190.

<sup>16</sup> The term *ghūlijāt* in the manuscript must be due to a missreading of a letter *Ṭā* as the sequence *Wāw-Lām* and a letter *Kā* without the upper stroke as an undotted letter *Jīm*.

<sup>17</sup> al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 142–143; Kennedy, Edward Stuart, 1976, : vol.1, 190–191.

<sup>18</sup> al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 142–143; Kennedy, Edward Stuart, 1976, : vol.1, 190–191.

وإذا سرّك أن تعرف ساعات النهار / فاتخذ عودا بعشر فعل ذى فهم يصار / يتبع درس بحور قد تمليّن غرار  
وليكن عودك فافهم طوله عشر أصابع

(Original orthography of the edition).

rhymes are found in another recently edited didactic poem by al-Fazārī.<sup>19</sup> Such poems, called *muzdawij*, became popular in Arabic *rajaz*-Poetry and later in the Persian *mathnawī*. Both were standard forms for didactic poems. There has been controversy over the origin of the Arabic *muzdawij*-form, and al-Fāzārī's *Qaṣīdah* is regarded as one of the earliest examples.<sup>20</sup> It has gone unnoticed that he had a predecessor. We may think of his solution with a triple internal rhyme as a hybrid form between the Indian *śloka* and the Arabic *Qaṣīda*. Alternatively it may have been inspired by Middle Persian rhymed verses.<sup>21</sup>

## Second Phase: Operations using Physical Models

After the eighth century, such didactic poems disappear almost entirely. Instead, instructional texts were written in prose. An early corpus of such texts by al-Khwārizmī is preserved.<sup>22</sup> They contain instructions on how to construct and how to use astronomical instruments.

A comparison between al-Khwārizmī's treatise on the astrolabe and corresponding earlier works in Greek and Syriac on this subject shows close similarities. However, al-Khwārizmī added new subject matters to those found in the earlier works. Furthermore, his treatise's style is different. Both, Johannes Philoponos and Severus Sebokht address readers in the first person plural.

Johannes Philoponos for example says:

If then we wish (*etheloimen*) to take the hour of the sun by the instrument  
in the daytime, we suspend (*artōmen*) the instrument from the ring in  
such a way that its quadrant, the one cut up into the 90 degrees, inclines

<sup>19</sup> Al-Qabīṣī, 'Abd al-'Azīz Ibn 'Uṭmān: *Kitāb al-mudkhal ilā ṣinā'at aḥkām al-nujum* 2004 : 365–369.

<sup>20</sup> Ullmann, Manfred: *Untersuchungen zur Raḡazpoesie*. Wiesbaden 1966 : 52.

<sup>21</sup> Personal communication by Mohsen Zakeri

<sup>22</sup> Charette, François and Schmidl, Petra G.: al-Khwārizmī and practical astronomy in ninth-century Baghdad the earliest extant corpus of texts in Arabic on the astrolabe and other portable instruments. *Sciamus* 5, (2004) 101–198.





the sun in line (*hādhi*) with your left shoulder. Place (*ij'al*) the 90 lines on the back of the astrolabe toward the centre of the sun. Then keep on raising the alidade until you see the sun entering both holes.

This change of tone from the inclusive first person plural in Greek and Syriac to the second person singular imperative is noteworthy, because it seems to reflect different social conditions in teaching. While the former tone fits the situation in a class room or lecture hall where a professor holds a public lecture in the presence of a demanding audience, the latter tone seems to indicate a situation where a superior master gives face-to-face instructions to a single subordinate disciple. At first it seems doubtful if these imagined situations have any informative value of the real teaching conditions in the respective societies. However, in the case of Greek astronomers in Late Antiquity more evidence is available and confirms the teaching format of lectures.<sup>27</sup> It would be an inappropriate generalization to conclude from this that the tone in Arabic works is similarly reliable evidence for real teaching conditions in Baghdad. Nevertheless, it seems promising to search an explanation for the changed style in the Arabic texts under consideration.

The use of the imperative singular is also found in an Arabic translation from a Sanskrit work. A fragment from an old translation of the *Brahmasphuṭasiddhānta* mentioned above is similar in style:<sup>28</sup>

Divide (*jazzi'*) a gnomon as we may desire, and measure (*qaddir*) the shadow by it, and add (*zid*) to it one of its units, and divide (*iqsim*) the result into the minutes of the amount of half the day(light).

However, in the corresponding Sankrit text the verbs are not in the imperative

<sup>27</sup> Pingree, David: The teaching of the Almagest in late antiquity. *Apeiron* 27, (1994b) 75–98;

<sup>28</sup> Kennedy, Edward Stuart, 1976, : vol.1, 189; al-Bīrūnī, Muḥammad Ibn Aḥmad, 1976, : 140–141:

جزّ المقياس على ما نريد وقدر الزلّ بها وزد عليه واحدا من آحاده واقسم على المبلغ دقائق مقدار نصف النهار فتخرج دقائق الماضي أو الباقي وفي عكسه قسم دقائق نصف النهار على دقائق الماضي أو الباقي ونقص مما خرج واحد فبقي الظلّ  
better read: جزّ for جرّ; cf. Kennedy, Edward Stuart, 1976, : vol.1, 189.

(XII.52):<sup>29</sup>

The half day being divided (*hṛtam* by the shadow (measured in lengths of the gnomon) added to one, the quotient is the elapsed or the remaining portion of day, morning or evening.

Here, the verb is in the form of a passive past participle. Nominal forms of verbs are prevalent in astronomical texts. In a passage in the *Pañcasiddhāntikā* of Varāhamihira on how to construct a celestial globe the verb is in the absolutive form (or gerund), but the modern editors translated them by imperatives (XIV.23):<sup>30</sup>

Construct (*prasādh*) a small sphere of wood having the measure of its surface evenly round; on its circumference (i.e. surface?) (draw) two lines (indicating) the passage of time, which are bent where the sun stops (i.e. at the two solstices).

This translation is more appropriate because at the beginning of the chapter the instruction starts with “Multiply it by two” (XIV.4).<sup>31</sup> Here, the imperative form *prasārya* (causative from *prasr*) is used.<sup>32</sup> Therefore, the absolutive forms are just unmarked continuations of this imperative, which sets the tone for the entire instructional text.<sup>33</sup>

<sup>29</sup>Colebrooke, Henry Thomas, editor: *Algebra, with arithmetic and mensuration from the Sanscrit*. London 1817 : 317; Brahmagupta: *Brāhmasphuṭasiddhānta* 1966 : v. 1, १६९:

छायांनरसैकहृतं द्युदलं प्रागपरयो द्युगतशेषम्  
दिनगतं शेषांशहृतं द्युदलं छायांनरव्येकम्  
chāyānaraśaikahṛtaṁ dyudalaṁ prāgaparayō dyugataśeṣam / dinagataṁ śeṣāṁśahṛtaṁ dyudalaṁ  
chāyāṁnaravyekam //

<sup>30</sup>Varāhamihira: *Pañcasiddhāntikā* 1970–1971 : v. 1, 128–129:

समवृत्तपृष्ठमानं सूक्ष्मं गोलं प्रसाध्य दारुमयम्  
ठिगितार्कसमङ्कितकालभोगरेखदृष्टये परिधपरिधौ  
samavṛttapṛṣṭhamānaṁ sūkṣmaṁ golaṁ prasādhyā dārumayam  
sthagītārkasamaṅkitakālabhogarekhādṛṭhaye paridhau.

<sup>31</sup>Varāhamihira, 1971, : v. 1, 122.

<sup>32</sup>Varāhamihira, 1971, : v. 1, 122: द्विगुणं प्रसार्य dviguṇaṁ prasārya.

<sup>33</sup>Cf. Whitney, William Dwight: *Sanskrit grammar: including both the classical language, and the older dialects, of Veda and Brahmana*. Cambridge, Mass. 2002 : 355 (§ 989).

It would be wrong to believe that imperative was the standard form for instruction in Arabic texts. In the Arabic translation of Ptolemy's *Almagest* by al-Ḥajjāj the first person plural of the Greek original is retained in the translation. The instruction of how to construct an instrument for ecliptic measurement starts in the original text:<sup>34</sup>

We make (*poiēsomen*) a bronze ring of a suitable size, turned on the lathe so that its surface is accurately squared off (i.e. has a rectangular cross-section). We use (*khṛēsometha*) this as a meridian circle, by dividing it into the normal 360° of a great circle, and subdividing each degree into as many parts as (the size of the instrument) allows.

The Arabic translation by al-Ḥajjāj reads:<sup>35</sup>

We make (*na'malu*) a bronze ring, suitable in size, perfectly round and quadratic in the surfaces. We take it (*nattakhidhuhā*) it as the line of the meridian and we divide it (*naqsimuhā*) into 360 parts in the manner of the division of a great circle, and each single of its part by what is possible in minutes.

Later, both styles, the first person plural style and the imperative form style, are used in astronomical works and occasionally side by side in the same work, but, as it seems, they have different origins.

This observation leads to more general considerations. The earliest Arabic texts on astronomy are based mainly on Sanskrit works, both in style and content. This would not have been possible without the personal contact with Indian astronomers. The nature of the known Sanskrit works makes it unlikely that they were used without

<sup>34</sup>Toomer, G. J., editor: *Ptolemy's Almagest*. Princeton 1998 : 61; Heiberg, Johan Ludvig, editor: *Claudii Ptolemaei opera quae exstant omnia: volumen I*. Leipzig 1898–1903 : 64, 12–16: ποιήσομεν γὰρ κύκλον χάλκεον σύμμετρον τῷ μεγέθει τετορνευμένον ἀκριβῶς τετράγωνον τὴν ἐπιφάνειαν, ᾧ χρῆσόμεθα μεσημβρινῷ διελόντες αὐτὸν εἰς τὰ ὑποκείμενα τοῦ μεγίστου κύκλου τμήματα τῆς καὶ τούτων ἑκάστον, εἰς ὅσα ἐγχωρεῖ μέρος

<sup>35</sup>Al-Ḥajjāj: *Al-Majisṭī* : f. 10v, 5–7: نعمل حلقة من نحاس مقتدرة العظم محكمة الحدود مربعة السطوح ونأخذها خطاً نصف النهار ونقسمها بثلاثمائة وستين جزءاً على قمسة الدائرة العظمى وقسم كل واحد من أجزائها بما يمكن من الدقائق.

further instructions from experienced specialists trained in the living tradition of Indian astronomy. The scarcity of style and the extensive use of synonymous technical terms makes their reading difficult. It would be wrong to see the earliest Arabic text as product of a mere “translation movement” without a broader process of acculturation in the early Abbasid epoch. The Barmakids are reported to have been active in the adaption of medical works from Sanskrit sources. The Barmakids themselves had an Buddhist educational background.<sup>36</sup> The important position which astronomer had at the court is likely to be another element of this acculturation process. One of the positions at royal courts in Ancient India was the *gaṇaka* (“calculator”), who was an expert in astronomy and astrology.<sup>37</sup> It is striking that a number of Arabic astronomers received the epithet *al-ḥāsib* (“calculator”), e.g. Aḥmad b. Muḥammad al-Nīhawandī (2nd half 8th / 1st half 9th c.),<sup>38</sup> Ḥabash (d. after 868)<sup>39</sup>, ‘Abdallāh b. Masrūr (1st half 10th c.),<sup>40</sup> and Ḥumayd b. ‘Alī (10th c. ?)<sup>41</sup>. Every astronomer was able to calculate, and therefore *al-ḥāsib* must have meant something particular like a function or an office. One explanation would be, that *al-ḥāsib* was a calque for Sanskrit *gaṇaka*, but the question needs thorough reasearch.

In a second stage in the time of al-Ma’mūn, subject matters from the Greek tradition appear in these texts perhaps through Syriac intermediates. But in style the Indian models are still present. Besides that, instructional texts based on Sanskrit works, both in content and style were still produced. This indicates that the aforementioned acculturation process was long lasting phenomenon. This has been emphasised in recent studies on other scientific disciplines.<sup>42</sup>

Therefore, one might argue that the social conditions for teaching astronomy in

<sup>36</sup>Bladel, Kevin van: The Bactrian background of the Barmakids. In *Islam and Tibet : interactions along the musk routes*, page 43–88. Ashgate.

<sup>37</sup>Plofker, Kim, 2009, : 179.

<sup>38</sup>Sezgin, Fuat, 1978, : 135.

<sup>39</sup>Sezgin, Fuat, 1978, : 173.

<sup>40</sup>Sezgin, Fuat, 1978, : 205.

<sup>41</sup>Sezgin, Fuat, 1978, : 282.

<sup>42</sup>Bladel, Kevin van, 2011, ;Beckwith, Christopher I.: *Warriors of the cloisters : the Central Asian origins of science in the medieval world*2012 .

Baghdād might have been similar to those of Indian societies.

In India there were larger institutions devoted among others things to learning. Temples provided the education of priests. Monasteries trained their novices in the religious disciplines. But from the few hints we have, it seems that astronomers received their education elsewhere. Like other specialists, disciples entered the house of a master and became temporarily a member of his family. After having finished their studies, they had an agreement and stayed a number of years in the service of their master, as compensation for their apprenticeship.<sup>43</sup> The relationship between master and pupil resembled that between father and son. Naturally, a son often followed the occupation of his father. Varāhamihira learned astronomy from his father, and his own son became an astronomer too.<sup>44</sup> Put briefly, astronomy was run as a family business, including the production, acquisition and preservation of manuscripts.

There is some independent evidence that comparable social conditions prevailed in the central and eastern part of the Islamic world. It is noteworthy that according to Arabic biographical works a considerable number of astronomers had family relations, e. g. ‘Umar b. al-Farrukhān and his son Muḥammad<sup>45</sup>, Rabban al-Ṭabarī and his son ‘Alī<sup>46</sup>, the Banū Mūsā<sup>47</sup>, the Banū Šabbāḥ<sup>48</sup>, Khālīd al-Marwarrūdhī and his grandson ‘Umar b. Muḥammad b. Ḥālīd<sup>49</sup>, Jābir b. Sinān al-Ḥarrānī and his son Muḥammad al-Battānī<sup>50</sup>, Khalaf al-Marwarrūdhī and his two sons Aḥmad and Muḥammad<sup>51</sup>, the Banū Amājūr and their famulus Mufliḥ<sup>52</sup>, Ḥabash and his son Abū Ja‘far<sup>53</sup>, ‘Abd al-

<sup>43</sup> Scharfe, Hartmut: *Education in ancient India*, volume 16 of *Handbook of oriental studies 2, India*. Leiden 2002 : 264–270.

<sup>44</sup> Varāhamihira, 1971, : vol. 1, 26–27; : vol. 4, 212.

<sup>45</sup> Sezgin, Fuat, 1978, : 137.

<sup>46</sup> Sezgin, Fuat, 1978, : 145.

<sup>47</sup> Sezgin, Fuat, 1978, : 147.

<sup>48</sup> Sezgin, Fuat, 1978, : 148.

<sup>49</sup> Sezgin, Fuat, 1978, : 137.

<sup>50</sup> Sezgin, Fuat, 1978, : 273.

<sup>51</sup> Sezgin, Fuat, 1978, : 162.

<sup>52</sup> Sezgin, Fuat, 1978, : 177.

<sup>53</sup> Sezgin, Fuat, 1978, : 173 .

Raḥmān al-Ṣūfī and his son Abū ‘Alī<sup>54</sup>, and Jābir b. Ibrāhīm and his son Ibrāhīm<sup>55</sup>. A case of four generations is the prominent Yaḥyā b. a. Maṣṣūr and his great-grandson Hārūn b. ‘Alī.<sup>56</sup> A single case from al-Andalus are the two brothers Ibn al-Ṣaffār<sup>57</sup>.

Further, it is conspicuous that according to the biographical works a significant flow of migration from east to west took place. A great number of astronomers working in Baghdad either came from Iran, Khurasan and Transoxania or had a family background in these regions. The *nisbah*-elements in the names reveal an origin from Farghana, Samarkand, Khawizm, Marw, Marw Arrudh or Balkh. In these regions Buddhism and Sankrit learning coexisted with Islamic culture and were amalgamated.<sup>58</sup>

At times, professional activities of astronomers in Baghdad were public affairs, but, if the above conclusions are valid, teaching was organized in private enterprises with small numbers of participants, a form which is also typical for the training of specialists in Sanskrit astronomy. In view of this, nobody would expect to find traces of large institutions in Baghdad where astronomy was taught. The misinterpretation of the *bayt al-ḥikmah* as an academy or university in earlier research might have been guided by a search pattern formed according to learning institutions at Alexandria in Late Antiquity.<sup>59</sup>

There are not many remains from the material culture of 9th century Baghdad. However, there exist two astronomical documents which deserve attention.

The first is a palimpsest in the Vatican Library (figure ??) containing parts of an Arabic translation of Theon's small commentary on the “Handy Tables” of Ptolemy. Its editor Delio Proverbio suggests that it was written in the scriptorium of the *bayt al-ḥikmah* and belonged to its library.<sup>60</sup>

<sup>54</sup> Sezgin, Fuat, 1978, : 212; Rosenfeld, Boris Abramovich and Ekmeleddin İhsanoğlu, 2003, : 87.

<sup>55</sup> Sezgin, Fuat, 1978, : 240.

<sup>56</sup> Sezgin, Fuat, 1978, : 216 .

<sup>57</sup> Sezgin, Fuat, 1978, : 250 .

<sup>58</sup> Elverskog, Johan: *Buddhism and Islam on the Silk Road*. Philadelphia 2010 : 56–116.

<sup>59</sup> See the article of Damien Janos in this volume.

<sup>60</sup> Proverbio, Delio Vania: Theonis asecandrini gragmentum pervetus arabice: Sul più antico manoscritto del commentarium parvum di Teone Alessandrino: nioizia preliminare. *Atti della Accademia Nazionale dei Lincei. Classe di Scienze Morali, Storiche e Filologiche. Rendiconti, ser. 9* 13, (2002) 373–386.

The second document is an astrolabe (Figure ??) which once was in the Iraq Museum in Baghdād but has disappeared. David King suggests that it was produced in early ‘Abbāsīd Baghdād.<sup>61</sup> One distinct feature compared with later astrolabes is its small size of 8.5 cm in diameter. Other early astrolabes from the 10th century are similar in size, a fact which excludes mere coincidence.<sup>62</sup> Small dimensions make an astrolabe unsuitable for professional observations and procedures. However, it is quite suitable for teaching, particularly small groups.

The use of a visual representation of the geometrical concepts promotes spatial sense, and the standard training procedure of manipulating the astrolabe's moveable parts is a fine example of what in modern educational psychology is called “observational learning” and “modeling”.<sup>63</sup> The success in learning from the astrolabe was enormous, both in the Islamic world and medieval Europe.

This raises the question of why this kind of teaching did not already happen in Antiquity. The answer could be that ... ????. Operational aspects of astronomy were of minor importance in the curriculum at the Alexandrian school. So there was no reason to stress the use of the astrolabe in educational texts. Therefore, texts on the use of astrolabes were marginal.

In the Indian tradition, the intentions underlying astronomical teaching were different. There, operational aspects were paramount, hence texts consist mainly of technical instructions on how to master the practical tasks. However, as the astrolabe was not known in India, the instrument was of limited use.

For scholars in Baghdad, trained in the Indian approach to astronomy, it must have been easy to realize the potential of the astrolabe as a practical aid and a training tool for performing astronomical procedures. This new demand found its solution and perfect tool, and hence the astrolabe was adopted in Baghdad and spread elsewhere.

<sup>61</sup>King, David A.: *In synchrony with the heavens. Studies in astronomical timekeeping and instrumentation in medieval Islamic civilization*. Leiden 2004–2005 : vol. 2, 403–433.

<sup>62</sup>King, David A., 2005, : vol. 2, 439–544.

<sup>63</sup>Bandura, Albert: Analysis of modeling processes. In *Psychological Modeling: Conflicting theories*. Aldine, Chicago.



This also caused the elaboration of new concepts of teaching, which, at the time, were different from those of the classical world.

### Third Phase: Lectures Using Textbooks

In the great schools of Late Antiquity, public lectures constituted the main form of teaching, as documented by the numerous commentaries.<sup>64</sup> In the case of astronomy, seven Greek commentaries on Ptolemy's *Almagest* from the third to the sixth centuries are known. The commentary of Theon of Alexandria is almost entirely preserved and seems to be an adaptation of his lectures in the school of Alexandria. According to Ibn al-Nadīm, Theon's commentary on the *Almagest* was translated into Arabic.<sup>65</sup>

It is striking that in the first century of Arabic astronomical literature the genre of commentary is absent. This indicates that the classical format of lectures based on text-books was not followed in the field of astronomy. The first commentaries of the *Almagest* were written towards the end of the ninth century.<sup>66</sup> Since they are not preserved, it is difficult to describe their character and to decide whether they were adaptations of lectures, or independent literary works containing personal scientific achievements as a commentary.

A candidate for the genre of lecture notes is a commentary by al-Qabīṣī on *al-Fuṣūl* by al-Farghānī.<sup>67</sup> Al-Qabīṣī was active as a teacher and tried to establish official exams for astronomers, but failed to get approval from the side of his patron, Sayf al-Dawla.<sup>68</sup>

Another commentary attributed to al-Fārābī is closer to the classical tradition. It is well known from biographical sources that al-Fārābī wrote a commentary on the *Almagest*. In 1978 Fuat Sezgin referred to a manuscript in the Majlis Library containing this work.<sup>69</sup> Unfortunately, the published shelfmark number was not correct and

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<sup>64</sup> Pingree, David, 1994b, .

<sup>65</sup> Sezgin, Fuat: *Geschichte des arabischen Schrifttums. Band V Mathematik*. Leiden 1974 : 180.

<sup>66</sup> Sezgin, Fuat: *Geschichte des arabischen Schrifttums. Band VI Astronomie*. Leiden 1978 : 90–91.

<sup>67</sup> Sezgin, Fuat, 1978, : 209.

<sup>68</sup> Sezgin, Fuat, 1978, : 209.

<sup>69</sup> Sezgin, Fuat, 1978, : 195.

earlier attempts to gain access to this manuscript in the Majlis library failed. However, the “Institute for the History of Arabic-Islamic Sciences” in Frankfurt owns a microfilm of this manuscript.

This hitherto unexplored manuscript, preserved in the Majlis Library in Tehran, is incomplete at the beginning and contains a commentary on the the end of book IX and on the books X–XIII of Ptolemy's *Almagest*. A modern title page attributes the text to al-Fārābī. The manuscript itself bears no information on authorship, and the cataloguer of manuscripts in the Majlis Library did not explain on what grounds he attributed text to al-Fārābī. Investigations on Arabic commentaries on the *Almagest* in general supported the conclusion that the the author of this text is most likely al-Fārābī's.<sup>70</sup>

This text shows distinctive features not found in any other known Arabic commentary on the *Almagest*. Among them are the following:

1. Its large size is only comparable to that of the Greek commentary of Theon of Alexandria. The preserved part covers about one third of the *Almagest* and fills 211 folios.
2. The commentary is verbose on the geometrical proofs, short in the reports of observations and patchy in passages on calculations.
3. The commentator closely identifies himself with Ptolemy as an author. He refers to the observations of Ptolemy in the first person, as if he had made them himself. However, at the end of chapter two of book XIII the commentator criticizes Ptolemy's philosophical digression on the meaning of simplicity in nature, and presents himself as a philosopher trained in physics and metaphysics.
4. Finally, the text makes no reference to Islamic astronomers and their improvements anywhere.

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<sup>70</sup>Thomann, Johannes: Ein al-Fārābī zugeschriebener Kommentar zum *Almagest* (Hs. Tehran Mağlis 6531). *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 19, (2010–2011) 35–76.

The beginning of book XIII may give an impression of the style which is employed:<sup>71</sup>

For us two things remain now from the knowledge of the movements of the five planets. One is the knowledge of the movement in latitude which occurs in their movement in the sphere of the ecliptic in the direction of its two sides. The other is on the distances from the sun which they reach when they become visible.

These and other features enable us to sketch the goals of the author and the nature of his audience. The author, presumably al-Fārābī, showed little interest in the numerical values of the model parameters, which is normally a primary concern for an astronomer. He was interested in the long step-by-step proofs leading to a thorough understanding of the abstract kinematic models. In doing so, he focused on purely mathematical aspects. This is the *raison d'être* for astronomy among mathematical disciplines within the program of the philosophical curriculum.<sup>72</sup>

Since no update of the Ptolemaic parameters is made, the text is unsuitable for the training of professional astronomers and bears no original scientific information that would make it valuable for astronomical research. Obviously, it seems to be a text entirely concerned with teaching. It was not addressed to future professional astronomers, but to students following a curriculum for the classical quadrivium of mathematical sciences.

Therefore, this text marks the revival of a philosophical education where mathematics play a crucial role. If the attribution to al-Fārābī is correct, it seems to directly counter his extensive efforts to create an appropriate form of musical theory as a discipline compatible to his own general philosophy of science.<sup>73</sup> These intentions

<sup>71</sup>MS Tehran Majlis 6531 f. 180r: وإذا قد بقي علينا بعد في علم أمر الكواكب الخمسة شيئا أحدهما علم ما يحدث من المسير في العرض بمسيرها حول فلك البروج وعن جنبتيه والآخر في الأبعاد التي إذا بلغت من الشمس ظهرت للأبصار بعد استسارها.

<sup>72</sup>Janos, Damien, 2012, : 43–84.

<sup>73</sup>For al-Fārābī's views on education see: Günther, Sebastian: The principles of instruction are the grounds of our knowledge. Al-Fārābī's philosophical and al-Ghazālī's spiritual approaches to learning. In *Trajectories of Education in the Arab World. Legacies and challenges*, page 15–35. RoutledgeRufai, Saheed Ahmad: Al-Fārābī and Ibn Sīnā as Islamic educational thinkers. A comparative and contrastive analysis. *Islamic*

seem close to those followed by the representatives of the Alexandrian school of Late Antiquity.

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